STUDIES OF DISPLAY SYMBOL LEGIBILITY

Part XIII. Studies of the Legibility of Alphanumeric Symbols in the BUIC Symbol

AUGUST 1966

G. Kinney
D. Showman

Prepared for
DEPUTY FOR ENGINEERING AND TECHNOLOGY
DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 7030
Prepared by
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FOREWORD

This report is one of a series describing symbol legibility for television display. Additional information on this topic may be found in the following reports: "Studies of Display Symbol Legibility: The Effects of Line Construction, Exposure Time, and Stroke Width," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-249, February 1963; "Studies of Display Symbol Legibility, II: The Effects of the Ratio of Width of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-440, July 1963; "Studies of Display Symbol Legibility, III: Line Scan Orientation Effects," by B. Botha, D. Shurtleff, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-138, May 1966; "Studies of Display Symbol Legibility, IV: The Effects of Brightness, Letter Spacing, Symbol Background Relation, and Surround Brightness on the Legibility of Capitol Letters," by D. Shurtleff, B. Botha, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-134, May 1966; "Studies of Display Symbol Legibility, V: The Effects of Television Transmission on the Legibility of the Common Five-Letter Words," by G. Kosmider, The MITRE Corp., Bedford, Mass., ESD-TR-65-135, May 1966; "Studies of Display Symbol Legibility, VI: Leroy and Courtney Symbols," by D. Shurtleff, and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-136, May 1966; "Studies of Display Symbol Legibility, VII: Comparison of Displays at 945- and 525-Line Resolutions," by D. Shurtleff and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-137, May 1966; "Studies of Display Symbol Legibility, VIII: Legibility of Common Five-Letter Words," by G. Kosmider, M. Young, and G. Kinney, The MITRE Corp., Bedford, Mass., ESD-TR-65-385, May 1966; "Studies of Display Symbol Legibility, IX: The Effects of Resolution, Size and Viewing Angle of Legibility," by D. Shurtleff, M. Marsetta, and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-65-411, May 1966; "Studies of Display Symbol Legibility, X: The Relative Legibility of Leroy and Lincoln/MITRE Alphanumeric Symbols," by D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-115, August 1966; "Studies of Display Symbol Legibility, XI: The Relative Legibility of Selected Alphanumerics in Two Fonts," by G. Kinney and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-116, August 1966; and "Studies of Display Legibility, XII: The Legibility of Alphanumeric Symbols for Digitalized Television," by G. Kinney, M. Marsetta, and D. Showman, The MITRE Corp., Bedford, Mass., ESD-TR-66-117, August 1966.

ABSTRACT

The legibility of alphanumerics for BUIC system displays was studied in three experiments. Four fonts, standard Leroy, Idealized Early BUIC, Idealized Late BUIC, and Simulated Late BUIC, were tested in single-symbol, controlled exposure-time, recognition tests. The Early BUIC font was less legible than standard Leroy; but after some symbol changes were made, the new font (Idealized Late BUIC) was more legible than the earlier font. When the improved alphanumerics were simulated to appear as they do on the display console, they were less legible than the Idealized alphanumerics. Symbol changes are recommended, and BUIC operators are urged to exercise caution in reading the displays.

G.C. Kinney

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ACKNOWLEDGMENTS

This study was partly supported by MITRE Project 417B, Continental Air Defense (CONAD) System, BUIC III. The authors are thankful for the materials and guidance supplied by Dr. M. L. Duffy.

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INTRODUCTION

One of the characteristics of a visual display that affects the operator's speed and accuracy of response is the legibility of each symbol in the displayed messages. Not all of the symbols in a message must be perceived equally well for the message to be understood, and any two messages may differ by only a symbol or two among the several symbols being shown. If one symbol is commonly mistaken for another, there is at least the potential danger that one message may be mistaken for another. In this case, the operator may choose an inappropriate response. To know which symbols may be mistaken for which others, and to be careful in designing the messages and in training the operators, can prevent operator errors when the system is working.

When an operator error occurs, the system user attempts to discover the reason for it and how to prevent similar errors in the future. Assuming that the operator knew the meanings of the symbols, an error indicates either that he understood the message, but made an error in responding, or that he misunderstood the message. If he misunderstood the message, he may have been inattentive or otherwise delinquent, or the message may not have been plainly displayed. Messages on visual displays are often hard to read because of symbol overlap, reflectances in the scope face, distractions of many kinds, and the fact that the symbols themselves are not easy to read. Any effort to improve or modify a visual display is aided when the readability of the symbols themselves is known.

Since the legibility of a set of symbols is determined by how quickly and accurately the symbols are seen and recognized [1], it is possible to collect information on the symbols in the laboratory which indicates how well they will fare in a system. A laboratory test of symbol legibility can be made by degrading the viewing conditions (by limiting the amount of time the subject sees the symbol) or by lowering the brightness and contrast between the symbol and its background until the subject makes errors of identification approximately 20 percent of the time. If these conditions are set up for a symbol font whose legibility is known to be good, such as standard Leroy lettering, then a second font can be studied under the same conditions, and its performance compared directly with that of the good font. The comparison is informative when it shows which symbols were confused with which others. This is done by showing the symbols

to the subject one at a time and recording which symbol was shown and which symbol the subject called out. The symbol shown and the symbol called can be arranged in a "confusion matrix" of errors that shows the intersymbol confusions for every symbol. [2] From this matrix, errors and confusions that may occur in the display system can be anticipated.

The symbols on the display surface usually do not appear with the neatness and accuracy of the idealized symbols used in a laboratory study. Fortunately, the effects of small differences in symbol detail do not generally appear in the intersymbol confusions, but in the overall rate of error. Some symbols not confused in the laboratory may be confused on the display, but if two symbols are confused with each other in the laboratory situation, they are apt to be confused with each other when they appear on the scope face. [3] The laboratory results help to predict which specific reading errors will occur in the system itself.

Three such laboratory tests which have been conducted at MITRE for the BUIC system are reported in this paper. In these tests, alphanumeric symbols were presented briefly one at a time to each subject and errors were recorded. Viewing conditions were the same in the three experiments. In the first experiment, the symbols tested were idealized illustrations of the alphanumerics appearing on the BUIC console, taken from the Air Defense Command BUIC Positional Handbook. These symbols, referred to as Idealized Early BUIC (Figure 1), were compared with standard Leroy alphanumerics (Figure 2), which had fewer errors than the BUIC. This result had been anticipated by BUIC personnel at MITRE who changed some symbols in order to improve the legibility of the BUIC font. (These symbol changes had not been tested.) This modified font (referred to as Idealized Late BUIC, Figure 3) was compared with Idealized Early BUIC in Experiment 2 of this paper. Since fewer errors were made with Idealized Late BUIC than with Idealized Early BUIC, the symbol changes were successful in reducing confusions.

Because the idealized symbols tested in Experiment 2 are degraded when they appear on the console, their legibility was tested when it appeared as it did on the display consoles. Therefore, a simulation of the display font (Simulated Late BUIC, Figure 4) was compared with Idealized Late BUIC in Experiment 3. Many more errors were made with Simulated Late BUIC than with Idealized Late BUIC. With both fonts, the most frequent confusion was between I and 1; and with the Simulated font, confusions among M, N, and H were also found. Changes in the I, 1, M, N, and H are recommended. In addition, the BUIC operators should be told that confusions may occur, especially among particular symbols, and they should be urged to exercise caution in reading the displays.

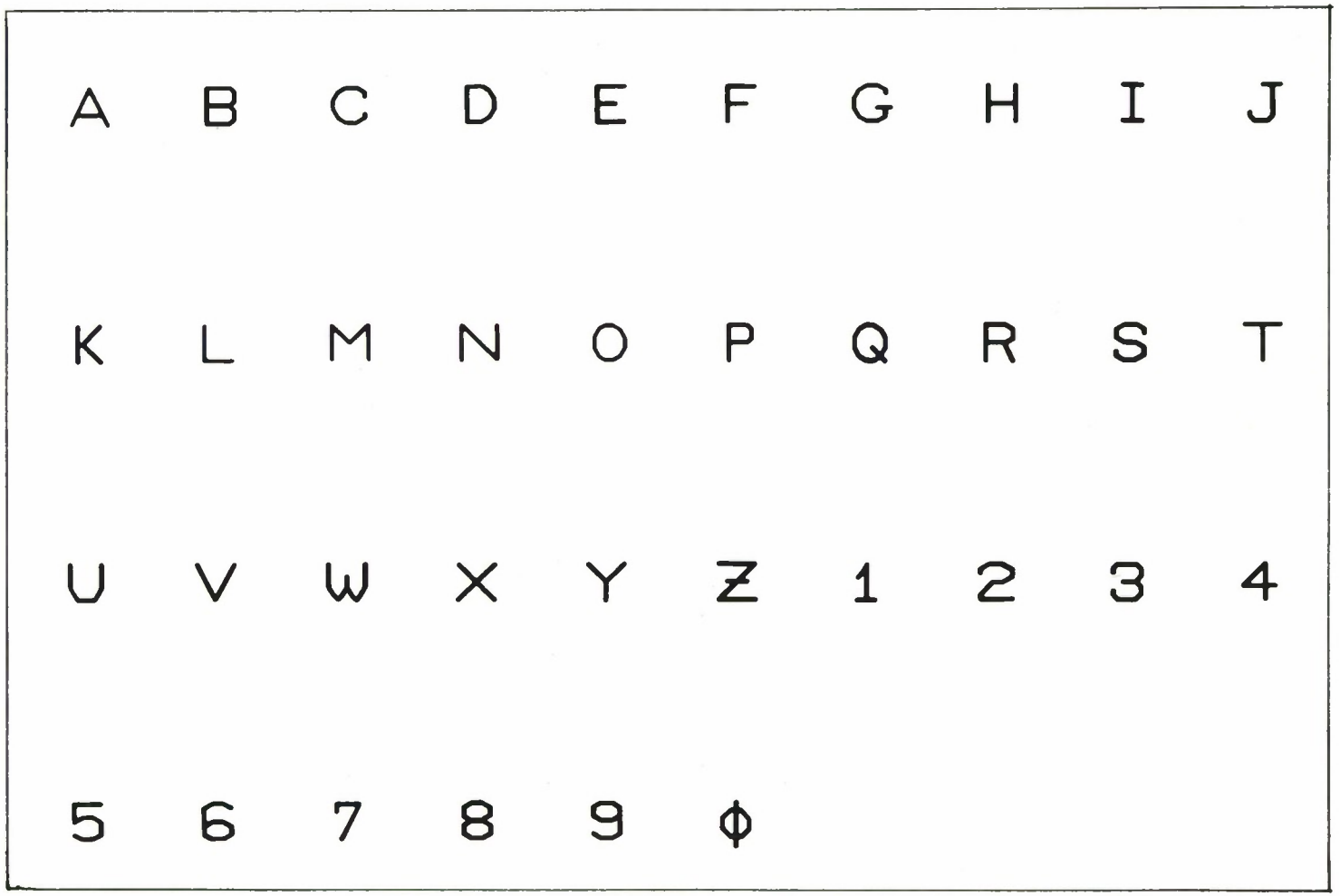

Figure 1. The Idealixed Early BUIC Alphanumerics Used in Experiments 1 and 2

Figure 2. The Leroy Alphanumerics Used In Experiment 1

Figure 3. The Idealized Late BUIC Alphanumerics Used in Experiments 2 and 3

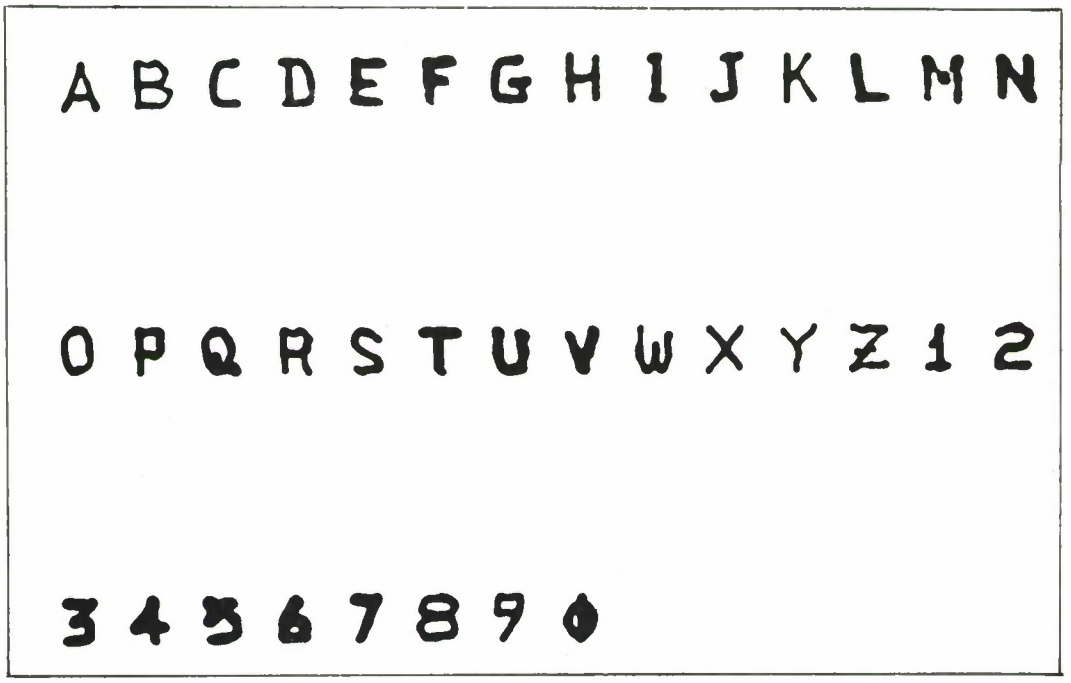

Figure 4. The Simulated Late BUIC Alphanumerics Used In Experiment 3

SECTION II

EXPERIMENT 1

APPARATUS

The Idealized Early BUIC symbols (taken from the Air Defense Command BUIC Positional Handbook) and the Leroy symbols were drawn on white cards and photographed on 35 mm DuPont Cronar Ortho A Litho film, with one symbol per frame. The symbols were clear on opaque backgrounds. One film strip with 180 symbols was made for each font: each of the 36 alphanumerics appeared 5 times at random with respect to alphabetic or numeric order on a film strip. The height of each symbol (in both fonts) subtended approximately 16 minutes of arc at the subject's eyes. The ratio of height to strokewidth was approximately 8.6 for the Idealized Early BUIC symbols and approximately 6.0 for Leroy.

The subject sat at a table on which was placed a tachistoscope (Figure 5). This device is a T-shaped tube with a rectangular cross-section arranged so that the subject can peer into one end of the cross of the T and see the other end at a distance of 54 inches. A beam splitter at the intersection of the cross and stem of the T reflects the image of the end of the stem and transmits the image of the opposite end of the cross at the same time. The two end spaces are visually superimposed and at the same apparent distance from the subject's eyes. The film bearing the symbols was passed behind a hole in the far end of the cross of the T.

The end of the stem of the T was covered with a fine-grained, white, styrofoam plastic and lighted continuously by an incandescent lamp. Four black lines were drawn on the white plastic in the form of a large plus sign with its center removed and arranged so that the center of the open space between the lines was visually coincident with the center of the hole for the film. With this background, the subject could fixate on the place where the symbol would appear when it was exposed. The symbols were lighted from behind by a battery-powered, incandescent lamp. A mechanical shutter was placed in the light path between the film and the lamp in order to control the duration of symbol exposure. The subject had a switch which operated the shutter.

The brightness of the background was measured through the eyepiece with a calibrated Spectra Brightness Spot Meter, and set to 1 foot-lambert. The brightness of the symbol was similarly set to 8 foot-lamberts, with

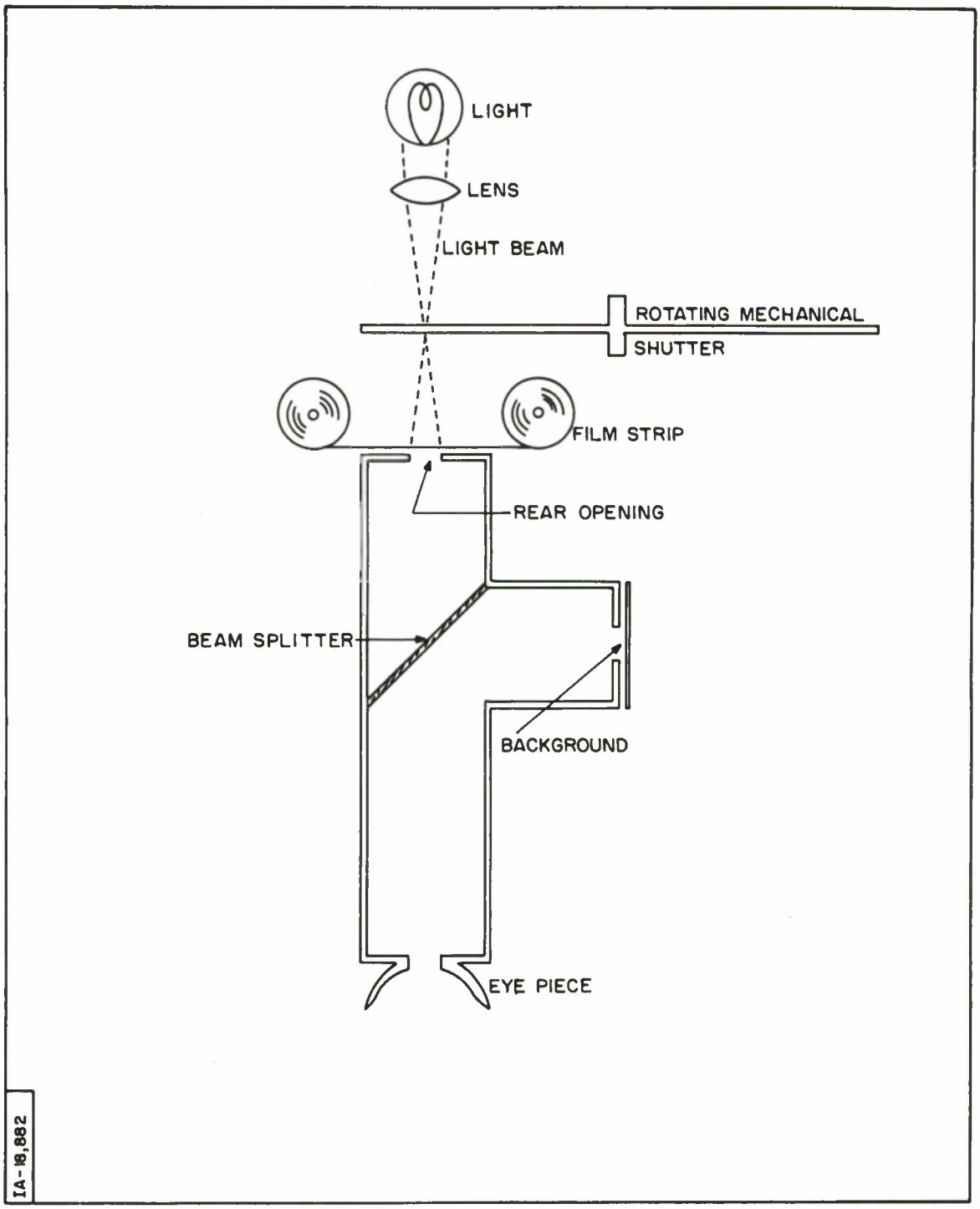

Figure 5. The Tachistoscope Used To Expose The Symbols To The Subjects

the background lighted, by putting a clear frame of the film at the film opening. Brightness measurements were made before and after each subject was tested. Symbol brightness varied no more than ± 0.5 foot-lambert, and background brightness no more than ± 0.1 foot-lambert from the settings. Both lamps were white in color.

The experiments were conducted in a sound-shielded room dimly illuminated by white fluorescent lamps. The subject's eyes were shielded from room illumination by the eyepiece.

PROCEDURE

Subjects were three MITRE employees who had been tested previously in similar experiments. Each subject's vision, corrected if necessary, was at least 20/20 as measured in the near acuity and far acuity tests of the Bausch and Lomb Ortho-Rater.

In each session the subject saw the 180 symbols of one font. When his eyes were focused on the fixation point and he was ready to see each symbol, he pressed the switch and exposed the symbol for 5 milliseconds. He was required to name one of the 36 alphanumerics every time a symbol was exposed; the symbol shown and the symbol called were recorded. By starting from either end of the film strip and by proceeding one or two frames at a time, the experimenter showed the symbols to the subject in a different order in each session. Three short rest periods were given during a session, dividing the session into quarters. In each session the subject was given a photograph of the symbol set to be seen, and he could refer to it at any time. Each subject was given two practice sessions with BUIC, and then was tested in two sessions with Leroy, followed by two more sessions with BUIC. Subjects were tested twice a day, once in the morning and once in the afternoon. The data from the sessions with Leroy and the last two sessions with BUIC were analyzed.

RESULTS AND DISCUSSION

Table I shows the errors made by the subjects for both fonts. There were more than twice as many errors made with the BUIC font as with Leroy. By inspection, the difference between fonts in total errors is statistically significant, and no test was made.

Table I

Errors Made in Experiment 1
(There were 1080 symbol exposures with each font.)

Subject	Session	Idealized Early BUIC	Sum	Leroy	Sum
1	1	49	89	9	27
	2	40		18	
2	1	15	41	12	27
	2	26		15	
3	1	12	32	8	17
	2	20		9	
Totals			162		71
Percent Error			15.0		6.6

The greater number of errors with BUIC is due, in part, to its narrower strokewidth. Previous work has shown that a narrow strokewidth can have an adverse effect on legibility; [4] for a review of studies testing the effects of different strokewidths on legibility, see Shurtleff. [1] Since the strokewidth of the symbols appearing on the display console is wider than that of the idealized symbols, no recommendation for wider strokewidth is made. Even though the greater error rate with BUIC cannot be attributed to symbol style alone (because of its narrower strokewidth), the kinds of errors made with BUIC are of interest because they help to predict the errors that will occur on the display console.

The confusion matrices showing the symbols called in error for each symbol shown are in Table II (Leroy) and Table III (Idealized Early BUIC). The confusions occurring most often with Leroy were 8-B (both 8 called B and B called 8), C-G, O-Q, O called C, and I called T. These confusions, involving 8 symbols, comprised 66 percent of the total error. With Idealized Early BUIC, the confusions occurring most often were C-G, O-Q, D called O, P called R, O called G, 8-B, 9-8, and J called 3. These confusions, involving 12 symbols, comprised 33 percent of the total error. The errors with Leroy were more concentrated in a few confusions than were the errors with BUIC; thus, the BUIC errors were not a simple multiple of the Leroy errors.

For the most part, the symbols in the most frequent confusions (C, G, O, Q, D, P, R, 8, B, 9, J, and 3) with Idealized Early BUIC were those with which the most errors were made. The font might be made more legible by modifying some of these symbols. Having anticipated this conclusion, BUIC personnel at MITRE made, but did not test, some symbol changes. Experiment 2 tested the effects of their design changes in the font.

Table II

Errors with Leroy in Experiment 1 for 3 Subjects, 2 Sessions Each (each symbol was shown 30 times).

Character Called

Character Shown	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	0	Σ
A																																					0
B																																		6		1	7
C							10																														10
D							1								1																						2
E																																					0
F																																					0
G			1																																		1
H																		1																			1
I																				4							1										5
J																																					0
K																																					0
L																																					0
M																																					0
N																																					0
O			5				3										5																				13
P						2												1																			3
Q							2								5																						7
R																																					0
S		1																																3			4
T																																					0
U																																					0
V																																					0
W																																					0
X																																					0
Y																						1															1
Z																																					0
1																																					0
2																																					0
3																															1						1
4																																					0
5		1																														3					4
6																																					0
7																																					0
8		11																																		1	12
9																																					0
Ø																																					0
Σ	0	13	6	0	0	2	16	0	0	0	0	0	0	0	6	0	5	2	0	4	0	1	0	0	0	0	1	0	0	0	1	3	0	9	0	2	71

Table III

Errors with Idealized Early BUIC in Experiment 1 for 3 Subjects, 2 Sessions Each (each symbol was shown 30 times).

Character Called

Character Shown

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	0	Σ
A							1											2																			0
B					1		1																											3			7
C							9								1																						10
D			1				2								6	2	1	1																			13
E						2																															2
F																																					0
G			3														1															1					5
H													1					1					1														3
I										1										4							1	1					2				9
J									2																				4									6
K													1									1																2
L					1																						1										2
M																																					0
N																																					0
O			2				5										7																	2	1		17
P						1												6																			7
Q				1			2								1																						4
R	1																																				1
S																																3		2			5
T																																	1				1
U															1								3														4
V																									1												1
W																																					0
X																																					0
Y																																					0
Z																												1					2				3
1									1	1																											2
2																										3								1			4
3		1					1											1	1							1					1	1		2	1		10
4																																					0
5					1											1			1												2						5
6					3		2												3											1							9
7																																		2			2
8		4																3	3												3			2			15
9		1																	3										3					4			11
Ø																														2							2
Σ	1	6	6	1	6	3	22	0	3	2	0	0	2	0	9	3	9	14	11	4	0	1	4	0	1	4	2	2	7	2	2	10	5	14	6	0	162

SECTION III

EXPERIMENT 2

APPARATUS

Changes had been made in the B, C, G, I, S, 3, 5, 6, 7, 8, and 9. The symbols of the modified font (Idealized Late BUIC, Figure 3) were drawn on white cards and photographed as before. The ratio of height to strokewidth was approximately 8.5, and the symbols were the same height as the Idealized Early BUIC symbols. The symbol brightness was again 8 foot-lamberts, varying not more than $\pm$ 0.5 foot-lambert, and the background brightness was 1 foot-Lambert, varying not more than $\pm$ 0.1 foot-lambert.

PROCEDURE

Three subjects were tested, two of whom had been tested in Experiment 1. These subjects were given two practice sessions with Idealized Late BUIC and then were tested in two sessions with Idealized Early BUIC followed by two sessions with Idealized Late BUIC. The third subject had two practice sessions with Idealized Late BUIC and two with Idealized Early BUIC, and then was tested in two sessions with Idealized Early BUIC followed by two sessions with Idealized Late BUIC. The experimental procedure was the same as in Experiment 1. Subjects were tested once a day. The data from each subject's last two sessions with each font were analyzed.

RESULTS AND DISCUSSION

Table IV shows the total errors and the percent error for the two fonts. Many more errors were made with the Idealized Early BUIC than with the Idealized Late BUIC symbols. Again, the difference is assumed to be statistically significant by inspection. Since the strokewidths of the two fonts were about the same, the low error rate with Idealized Late BUIC was due to the changes made in the symbols. (With Idealized Early BUIC, the number of errors is much lower in Experiment 2 than in Experiment 1. One possible reason for the lower overall error rate in this experiment is that the subject making the most errors in Experiment 1 was not used in Experiment 2.)

Table IV

Errors Made in Experiment 2
(There were 1080 symbol exposures with each font.)

Subject	Session	Idealized Early BUIC	Sum	Idealized Late BUIC	Sum
1	1	13	31	4	8
	2	18		4	
2	1	19	33	1	2
	2	14		1	
3	1	8	20	2	3
	2	12		1	
Totals			84		13
Percent Error			7.8		1.2

Table V

Errors with Idealized Early BUIC in Experiment 2 for 3 Subjects, 2 Sessions Each (each symbol was shown 30 times).

Character Called

Character Shown	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	0	Σ
A																																						0
B																	1												1					2				4
C							7										1																					8
D							2								5		2																					9
E																																					0
F																		1																			1
G																																					0
H																							1														1
I																				1							3										4
J									1																												1
K																																					0
L																											1										1
M														1																							1
N																																					0
O			1	1													5															1					8
P																		3																			3
Q							1								2																					1	4
R																																				1	1
S																															1			1	1		3
T																																					0
U																						1															1
V																																					0
W																																					0
X																																					0
Y																																					0
Z																												1									1
1																																					0
2																										3								1			4
3																																		1			1
4																																					0
5																			2													2					4
6		1				1		1																							2			1			6
7																																					0
8		8																														2			1		11
9																			4										1			1		1			7
Ø																																					0
Σ	0	9	1	1	1	0	11	0	1	0	0	0	0	1	7	0	9	4	6	1	0	1	1	0	0	3	4	1	2	0	3	6	0	7	2	2	84

Table VI

Errors with Idealized Late BUIC in Experiment 2 for 3 Subjects, 2 Sessions Each (each symbol was shown 30 times).

Character Called

Character Shown	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	0	Σ
A																																1					0
B																																					1
C																																					0
D																																					0
E																																					0
F																1																					1
G																																					0
H																																					0
I																											5										5
J																																					0
K																																					0
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1									1																												1
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6																																					0
7																																					0
8		1																	1																		2
9																																					0
Ø																																					0
Σ	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	5	0	1	0	0	1	0	1	0	0	13

The distributions of errors for the two fonts are shown in Tables V and VI. Table V (for Idealized Early BUIC) shows that the most frequently occurring confusions were 8-B, C called G, O-Q, D-O, and 9-S, these comprising about 42 percent of the total error. All of the confusions except the 9-S confusion (which does occur in Experiment 1) were also frequent confusions in Experiment 1. With Idealized Late BUIC (Table VI), the only confusion of note was I-1, which alone accounted for 46 percent of the few errors made. Shortening the bars on the I apparently eliminated the I called T confusion, but increased confusion between I and 1. The other symbol changes were apparently successful in reducing confusions.

The modified font was better than the earlier font, but how legible would it be when viewed on the display console? In Experiment 3, the Idealized Late BUIC symbols were compared with Late BUIC symbols simulated to appear as they do on the display console.

SECTION IV

EXPERIMENT 3

APPARATUS AND PROCEDURE

The alphanumerics displayed on the BUIC console were photographed, and enlarged prints of the symbols were made from the negatives. These prints were photographed on 35 mm film. Symbol height was the same as in the other film strips, and strokewidth was variable. A sample of symbols representative of the entire set on the film strip was measured; the ratio of height to strokewidth in the sample varied from 8.3 to 4.0, averaging approximately 5.8.

The apparatus, procedure, and subjects were the same as in Experiment 2. Symbol brightness varied no more than $\pm$ 0.3 from the setting of 8 foot-lamberts, and background brightness no more than $\pm$ 0.1 from 1 foot-lambert. Subjects had three sessions with each font arranged in an order to balance the effects of practice. The data from each subject's third session with each font were analyzed. Subjects were tested once a day.

RESULTS AND DISCUSSION

Table VII shows the total errors and the percent error made by the subjects with the two fonts. Many more errors were made with Simulated Late BUIC than with Idealized Late BUIC. The difference again is assumed to be statistically significant, and no test was made. Idealized Late BUIC proved more legible than Simulated Late BUIC. With Idealized Late BUIC, the percent error in Experiment 3 was greater than in Experiment 2, although it was still very low (3.1 percent).

The confusion matrices are shown in Tables VIII, IX, and X. Table VIII, for Idealized Late BUIC, shows that (as in Experiment 2) the I-1 confusion occurred most often and that the Q called G and R called P confusions also occurred. These confusions, involving 6 symbols, comprised 59 percent of the error. With Simulated Late BUIC, the most frequently occurring confusions were I-1, M-N, and M-H; lesser confusions were D called B, 5 called B, 8 called B, Q called O, Z called 7, and 5 called 3. These confusions, involving 14 symbols, comprised 56 percent of the error. The errors with Simulated Late BUIC were more scattered than were those of Idealized Late BUIC.

Table VII

Errors Made in Experiment 3
(There were 540 symbol exposures with each font.)

Subject	Idealized Late BUIC	Simulated Late BUIC
1	6	17
2	8	15
3	3	16
Totals	17	48
Percent Error	3.1	8.9

Table VIII

Errors with Idealized Late BUIC in Experiment 3 for 3 Subjects, One Session Each (each symbol was shown 15 times).

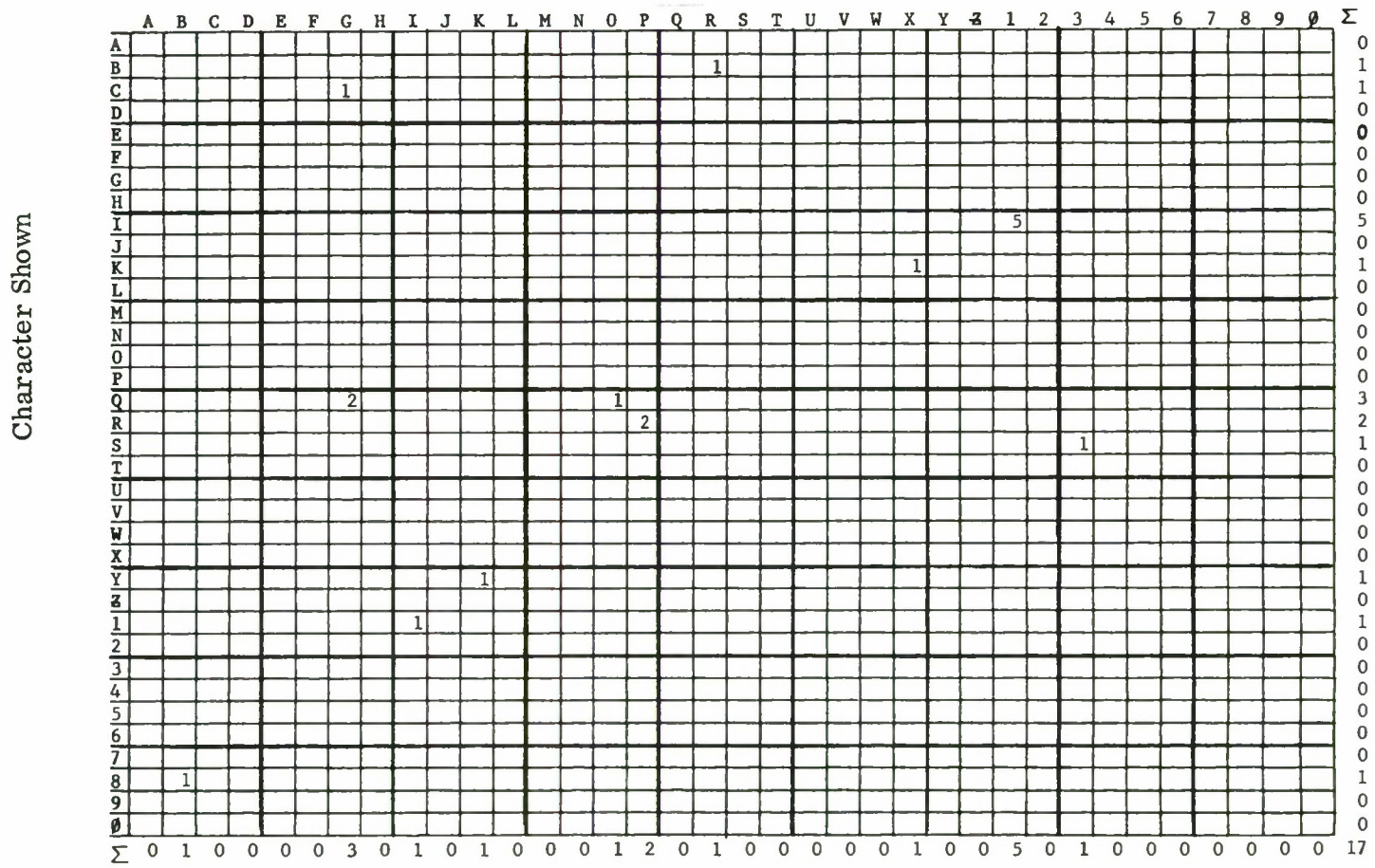


Table IX

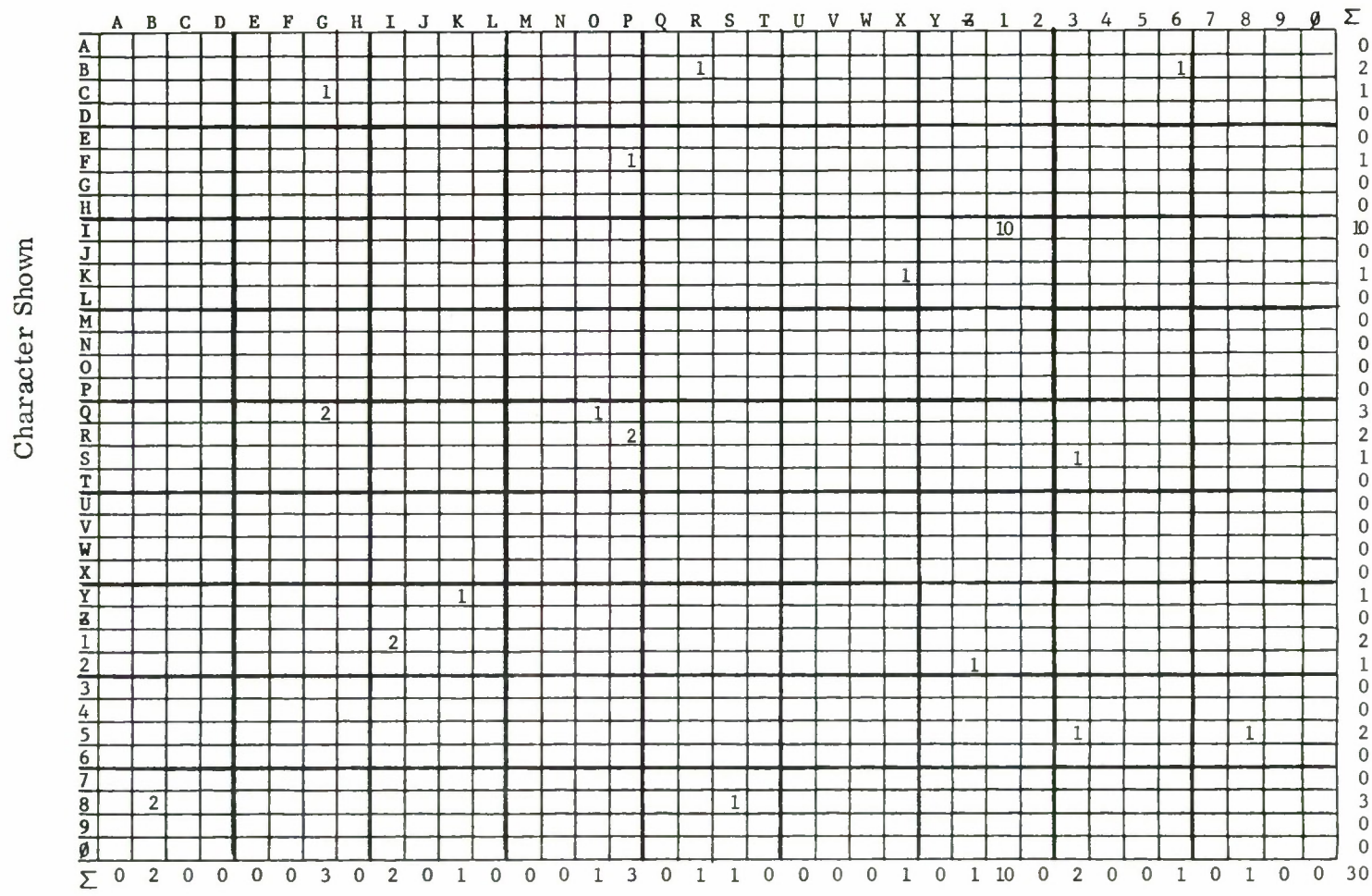
Errors with Simulated Late BUIC in Experiment 3 for 3 Subjects, One Session Each (each symbol was shown 15 times).

Character Called

Character Shown	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3	4	5	6	7	8	9	0	Σ
A																																					0
B																		1	1																		2
C																																					0
D		2																																			2
E						1																															1
F											1																										1
G																			1													1					2
H													1	1																							2
I																											4										4
J									1																												1
K						1																															1
L																											1										1
M								2						4																							6
N								1					1																									2
O				1			1																														2
P																																				1	1
Q															2																						2
R																																					0
S																																					0
T																																					0
U																																					0
V																																					0
W																																					0
X																																					0
Y																				1				1													2
Z																																1	2				3
1									3																												3
2																		1																			1
3																																					0
4																																					0
5		2																												2							4
6																															1						1
7																																					0
8		2																	1																		3
9																																					0
0															1																						1
Σ	0	6	0	1	0	2	1	3	4	0	1	0	2	5	3	0	0	2	3	1	0	0	0	1	0	0	5	0	2	1	0	2	2	0	0	1	48

Table X

Errors with Idealized Late BUIC from Experiments 2 and 3 Combined (each symbol was shown 45 times).



A comparison of the often confused symbols of Simulated Late BUIC (Table IX) with those of Idealized Late BUIC (Table VIII) shows that seven of the 10 Idealized Late BUIC symbols which were missed at least once were also missed at least once with the Simulated font. To some extent, the errors with the Simulated font may be predicted from the errors with the Idealized font. No rank correlation (of the symbols ranked from greatest to least errors) [5] was done because the few errors with both fonts resulted in too many rank ties.

To give a larger number of errors, the errors with Idealized Late BUIC from Experiments 2 and 3 were combined (Table X), and the specific confusions were compared with those of the Simulated font. With both the Simulated and the Idealized fonts, the I-1 confusion occurred most often. Confusions involving the M, N, and H, which did not occur at all with the Idealized font, were 21 percent of the error with the Simulated font. Since the error rate was low for the two fonts, a more detailed comparison of specific confusions is unwise. Recommendations about the I, 1, M, N, and H are discussed below.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

The conclusions are as follows:

1. Leroy was more legible than Idealized Early BUIC; it cannot be firmly concluded that the Leroy style is better because of the difference in strokewidths.

2. Idealized Late BUIC was more legible than Idealized Early BUIC.

3. The I and 1, the symbols in the only frequent confusion with Idealized Late BUIC, should be modified.

4. Idealized Late BUIC was more legible than Simulated Late BUIC.

5. With Simulated Late BUIC, the I-1 confusion and confusions between M, N, and H suggest the need for symbol changes.

In selecting designs for the I and 1, some previous work is relevant. An I with wider bars and gaps where the stem meets the bars, and a 1 with no serifs may result in fewer confusions between I and 1. At M.I.T.'s Lincoln Laboratory, [2], I with wider bars was not confused with the 1, with no serifs (see Figure 6). Lincoln Laboratory's I and 1 were used by Sanders (unpublished study) [1] and by Showman [6] at MITRE. In both of these earlier studies, I-T and I-1 were among the most frequently occurring confusions, but errors on these two confusions were a much smaller proportion of the total error than were the I-1 errors with Simulated and Idealized Late BUIC in the present experiments. It appears that the I and 1 in Figure 6 are preferable to the I and 1 of the Late BUIC font. No specific changes for the M, N, and H are recommended in this report because the errors are too small to be important. If symbols are modified, the modified font should be tested in a situation simulating that of the display, or, in the actual display situation, if possible.

The Late BUIC font now appears on the BUIC II console, and will appear on the BUIC III console. Although it is more legible than the Early BUIC font, operators should be warned that the symbols may be confused, particularly the I, 1, M, N, and H. The often confused symbols should be used as little as possible in places where the confusion of one symbol for another could introduce an operator error during system operations.

Figure 6. The Lincoln/MITRE Alphanumerics Tested By Showman
(Developed from Alphanumerics tested by Harris et al. at Lincoln Laboratory)

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13. ABSTRACT

The legibility of alphanumerics for BUIC system displays was studied in three experiments. Four fonts, standard Leroy, Idealized Early BUIC, Idealized Late BUIC, and Stimulated Late BUIC, were tested in single-symbol, controlled exposure-time, recognition tests. The Early BUIC font was less legible than standard Leroy; but after some symbol changes were made, the new font (Idealized Late BUIC) was more legible than the earlier font. When the improved alphanumerics were simulated to appear as they do on the display console, they were less legible than the Idealized alphanumerics. Symbol changes are recommended, and BUIC operators are urged to exercise caution in reading the displays.

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